



Recommendation ITU-R M.1478-3
(09/2014)

**Protection criteria for Cospas-Sarsat search
and rescue instruments in the band
406-406.1 MHz**

M Series
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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R M.1478-3

Protection criteria for Cospas-Sarsat search and rescue instruments in the band 406-406.1 MHz

(2000-2004-2011-2014)

Scope

This Recommendation provides protection criteria for Cospas-Sarsat search and rescue instruments placed on-board satellites in geostationary, medium-Earth and low-Earth orbits (LEO) and receiving signals from emergency position indicating radio beacons (EPIRBs) and other distress beacons operating in the 406-406.1 MHz band.

Keywords

Cospas-Sarsat; protection criteria; search and rescue instruments; 406-406.1 MHz.

Abbreviations/Glossary

EPIRBs - emergency position indicating radio beacons

DRU - data recovery unit

GOES - geostationary operational and environmental satellites

MSG - METEOSAT second generation

SARP - search and rescue processor

SARR - search and rescue repeaters

Related ITU Recommendations, Reports

Recommendation ITU-R M.1731-2 Protection criteria for Cospas-Sarsat local user terminals in the band 1 544-1 545 MHz

Recommendation ITU-R M.1787-2 Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz

The ITU Radiocommunication Assembly,

considering

- a) that the Cospas-Sarsat global satellite-based search and rescue system operates within an exclusive allocation in the band 406-406.1 MHz;
- b) the analysis provided in Annex 1 concerning maximum allowable spectral power flux-density (spfd) requirements of the Sarsat Search and Rescue Processor (SARP) against broadband out-of-band emissions and the upper bound on Doppler frequency shift associated with MSS transmissions received by Sarsat;
- c) the analysis provided in Annex 2 concerning maximum allowable power flux-density (pfd) requirements for the Sarsat SARP against narrow-band spurious emissions;
- d) that Annex 3 provides guidelines for using the protection requirements of the 406-406.1 MHz band for the Sarsat SARP instruments (on-board satellite equipment);

- e) that Annex 4 provides guidelines for protection of the primary safety services allocated in the band 406-406.1 MHz (C-S system) from non-GSO mobile-satellite service (MSS) downlink emissions below 406 MHz;
- f) that Annexes 5, 6 and 7 provide guidelines for the protection of 406-406.1 MHz search and rescue repeaters (SARR) on Sarsat LEO satellites, geostationary operational and environmental satellites (GOES) and meteosat second generation (MSG) satellites respectively;
- g) that Annexes 8 and 9 provide guidelines for the protection of 406-406.1 MHz search and rescue repeaters (SARR) on geostationary satellites (Electro) and navigational satellites (GLONASS) respectively;
- h) that Annex 10 provides guidelines for the protection of 406-406.1 MHz search and rescue repeaters (SARR) on navigational satellites (Galileo);
- i) that Annex 11 provides an overall synthesis of the characteristics of all instruments in current and future operation on board the various types of satellites in LEO, MEO or GSO orbits,

recommends

- 1 that analysis to determine the effect upon Sarsat SARP instruments by systems using adjacent frequency bands should be based upon a maximum acceptable spfd at the Sarsat antenna of $-198.6 \text{ dB(W/(m}^2 \cdot \text{Hz))}$;
- 2 that analysis to determine the effect upon the Sarsat SARP instruments from narrow-band spurious emissions (e.g. harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products) should be based upon a maximum pfd of $-166.2 \text{ dB(W/m}^2)$ at the Sarsat antenna within a resolution bandwidth of 19 Hz;
- 3 that analysis to determine the effect upon Cospas SARP instruments by systems using adjacent frequency bands should be based upon a maximum acceptable spfd at the Cospas antenna of $-198.6 \text{ dB(W/(m}^2 \cdot \text{Hz))}$;
- 4 that analysis to determine the effect upon the Cospas SARP instruments from narrow-band spurious emissions (e.g. harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products) should be based upon a maximum pfd of $-170.6 \text{ dB(W/m}^2)$ at the Cospas antenna within a resolution bandwidth of 40 Hz;
- 5 that analysis to determine the effect upon Cospas-Sarsat non-GSO instruments by proposed MSS systems using the 405-406 MHz frequency band should utilize an upper bound Doppler shift of 20 kHz;
- 6 that analysis to determine the effect upon Sarsat LEO repeaters by systems using adjacent frequency bands should be based on a maximum spfd at the Sarsat antenna of $-181.3 \text{ dB (W/(m}^2 \cdot \text{Hz))}$;
- 7 that analysis to determine the effect upon GOES GEO repeaters by systems using adjacent frequency bands should be based on a maximum spfd at the Sarsat antenna of $-201.1 \text{ dB (W/(m}^2 \cdot \text{Hz))}$;
- 8 that analysis to determine the effect upon MSG GEO repeaters by systems using adjacent frequency bands should be based on a maximum spfd at the Sarsat antenna of $-206.4 \text{ dB (W/(m}^2 \cdot \text{Hz))}$;
- 9 that analysis to determine the effect upon Electro GEO repeaters by systems using adjacent frequency bands should be based on a maximum spfd at the Cospas antenna of $-198.7 \text{ dB (W/(m}^2 \cdot \text{Hz))}$;

10 that analysis to determine the effect upon GLONASS MEO repeaters by systems using adjacent frequency bands should be based on a maximum spfd at the Cospas antenna of $-205.2 \text{ dB (W/(m}^2 \cdot \text{Hz))}$;

11 that analysis to determine the effect upon Galileo MEO repeaters by systems using adjacent frequency bands should be based on a maximum spfd at the antenna of $-206.1 \text{ dB (W/(m}^2 \cdot \text{Hz))}$;

12 that analysis to determine the effect upon the Galileo MEO repeaters from narrow-band spurious emissions should be based upon a maximum pfd of $-166.2 \text{ dB(W/m}^2)$ at the antenna.

Annex 1

Protection criteria for Cospas-Sarsat in the band 406-406.1 MHz against out-of-band broadband emissions

1 Introduction

This Annex provides information relating to the C-S system and its protection requirements from broadband out-of-band emissions.

2 Background

Other ITU texts provide substantial information concerning the following items:

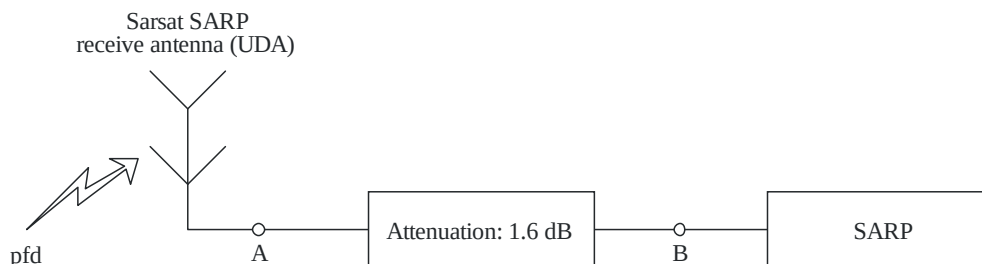
- parameters of several non-GSO MSS networks;
- pfd threshold level of interference;
- search and rescue (SAR) protection using spectral shaping or filtering techniques.

3 spfd threshold level of interference

The addition of broadband noise to the Sarsat SARP will have the effect of increasing the system bit error ratio (BER), and therefore adversely affect its performance. As identified in ITU-R studies the maximum acceptable uplink BER for the Sarsat SARP cannot exceed 5×10^{-5} . Based upon this requirement, this analysis identifies the maximum acceptable pfd associated with broadband noise in the Sarsat SARP uplink channel. The analysis does not address the effect of narrow-band emissions (e.g. spectral lines), which will also adversely affect the SARP's performance nor does it address the protection requirements for all C-S instruments (e.g. Sarsat search and rescue repeater, Cospas SARP).

Figure 1 shows the main hardware elements on board the NOAA satellites (and on the future METOP satellites).

FIGURE 1
On-board hardware equipment



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The UDA antenna gain pattern specification is expressed according to the nadir angle in Table 1:

TABLE 1
SARP receive antenna (UDA) gain pattern

Nadir satellite angle	62	59	54	47	39	31	22	13	5	0
Gain in RHCP	3.85	3.54	2.62	1.24	-0.17	-1.33	-2.24	-3.08	-3.80	-3.96
Gain in LHCP	-5.69	-6.23	-7.52	-9.39	-11.39	-13.12	-14.52	-15.77	-17.17	-18.00
Axial ratio	6.02	5.85	5.59	5.26	4.90	4.57	4.31	4.11	3.78	3.49

The specified figures in Table 1 are of the 406 MHz-Sarsat receive antenna pattern for the SARP, as they should be for the NOAA and METOP satellites.

The Sarsat typical figures are: noise figure = 2.5 dB (C-S SARP input parameter), nominal background noise temperature = 1000 K (C-S input parameter), attenuation between the antenna and the SARP receiver = 1.6 dB. Thus, the system noise temperature at the input of the SARP receiver (point B on Fig. 1) equals 1010 K and therefore, the noise spectral density equals $N_0 = -198.6$ dB(W/Hz).

The worst-case specification states that the SARP is designed to operate correctly when the received signal has a power $C = -161$ dBW (minimum level of the received signal) at the input of the receiver, which provides an effective $E_b/N_0 = 9.1$ dB in the bit detector of the SARP if we take into account the beacon waveform and the various losses. In this case, the corresponding BER equals 2.6×10^{-5} .

Therefore, in order to achieve a BER of 5×10^{-5} (which is an approximate doubling of the BER) the maximum acceptable degradation is 0.3 dB. At $E_b/N_0 = 8.8$ dB, the BER equals 4.8×10^{-5} .

Hereunder, the additive noise corresponding to the 0.3 dB degradation for the C/N_0 is calculated.

Let I_0 represent the additive noise power density coming from the non-GSO MSS interferers.

The initial N_0 noise becomes $N_0 + I_0$.

The signal-to-noise ratio C/N_0 becomes $C/(N_0 + I_0)$.

The degradation is $0.3 \text{ dB} = 10 \log ((C/N_0)/(C/(N_0 + I_0)))$, thus $I_0/N_0 = -11.5$ dB and $I_0 = -210.1$ dB(W/Hz) which corresponds to a temperature of 70.8 K, and therefore an increase of 7% of the system noise temperature at the input of the SARP receiver.

Therefore, the maximum admissible level of noise density is $I_0 = -210.1$ dB(W/Hz) (calculated for point B in Fig. 1).

As shown in Fig. 1, the noise density, I_0 , takes into account the attenuation and the antenna gain. As the spfd is required, it is necessary to transform this figure in dB(W/(m² · Hz)). The equivalent surface area of an antenna having a gain G is $S = G \frac{\lambda^2}{4\pi}$. Therefore, the corresponding spfd equals $-210 + 1.6$ (losses) $- 10 \log_{10} S = -198.6$ dB(W/(m² · Hz)), taking into account the highest satellite nadir angle.

The maximum level of broadband noise interference in the band 406-406.1 MHz shall not exceed -198.6 dB(W/(m² · Hz)) to protect the Sarsat SARP instrument.

4 Upper bound on Doppler shift

Any proposed protection bandwidth should also account for the Doppler shifts. The value of the maximum Doppler shift must be carefully examined. The worst case occurs when the Sarsat and the non-GSO MSS satellites are located on the same orbit and travel in opposite directions. In this case, the analysis below applies.

The non-GSO MSS signal comes from point A. The Sarsat satellite is represented by point B. The Sarsat satellite is moving at a speed V_B . If the non-GSO MSS satellite is not moving, the received frequency at B is $F_B = F_A (1 + \frac{V_B}{c})$ in the worst case. On the other hand, the received frequency at B has the same value if the Sarsat satellite is not moving and if the non-GSO MSS satellite is moving. If the altitude of the satellite equals 850 km, its speed is 7 426 m/s.

As the two satellites are moving in opposite directions, the upper bound Doppler shift equals:

$$2F_A (V_B/c) = 20 \text{ kHz}$$

This is a worst-case situation and is not necessarily applicable to all the proposed MSS systems.

5 Conclusions and recommendations

Following the above computations, the conclusions and recommendations regarding the impact of emissions from adjacent frequency bands on the Sarsat SARP are:

- the maximum level of broadband noise interference in the band 406-406.1 MHz shall not exceed -198.6 dB(W/(m² · Hz)) to protect the Sarsat SARP instrument;
- the upper bound on Doppler shift is 20 kHz;
- it is recommended that further analyses be conducted to determine the impact on C-S from MSS occupying the 405-406 MHz band using an spfd of -198.6 dB(W/(m² · Hz)), an appropriate Doppler shift and accounting for the worst-case scenario associated with the entire MSS constellation as envisaged.

Annex 2

Protection criteria for C-S system in the band 406-406.1 MHz against narrow-band spurious emissions

1 Introduction

This Annex provides information relating to the C-S system and its protection requirements against narrow-band spurious emissions.

2 Background

Annex 1 contains the protection criteria for Sarsat SARP in the band 406-406.1 MHz to be used as a basis for analysis of interference from out-of-band emissions. This Annex provides protection requirements for the Sarsat SARP instrument in respect of interference from narrow-band spurious emissions (harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products).

The terminology used in this Annex is derived from Recommendation ITU-R SM.328 – Spectra and bandwidth of emissions, and from Recommendation ITU-R SM.329 – Unwanted emissions in the spurious domain.

This Annex addresses protection criteria for only Sarsat SARP instruments and does not necessarily represent the protection criteria for all Cospas-Sarsat instruments.

3 Protection requirement from narrow-band spurious emissions

Figure 1 shows the main Sarsat SARP hardware elements.

To better understand the rationale of this specification, it is necessary to briefly recall the functioning of the SARP instrument.

Sarsat distress beacon transmissions begin with 160 ms of unmodulated carrier to allow a phase-locked loop to lock more easily on the carrier. Figure 2 represents the C-S message format.

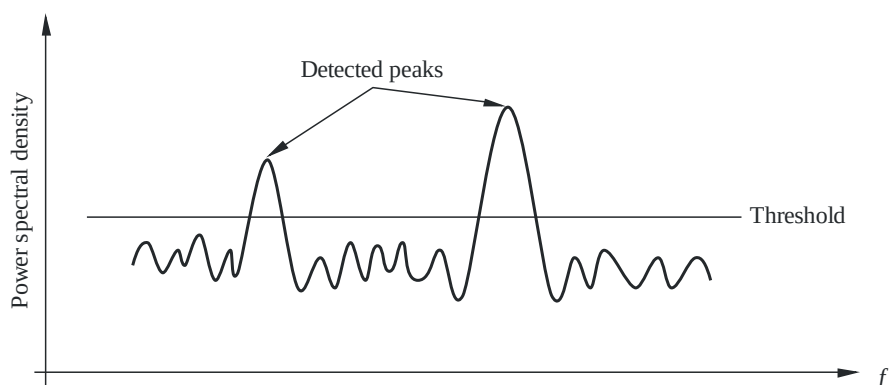
FIGURE 2
C-S message format

160 ms carrier	Synchronization bits	Distress beacon message content bits
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A spectrum analyser in the SARP instrument continuously monitors the full coverage bandwidth in search of the pure carrier portion of distress beacon transmissions. When the spectrum analyser detects such a line, it considers that it is the beginning of a C-S message. The theory is based on the detection of a pure carrier wave (sine wave) in a white, additive and Gaussian noise environment. The power spectral density of the received signal (pure carrier + noise) is computed using fast Fourier transform techniques, and each signal above the system threshold is processed as if it were a distress beacon (see Fig. 3).

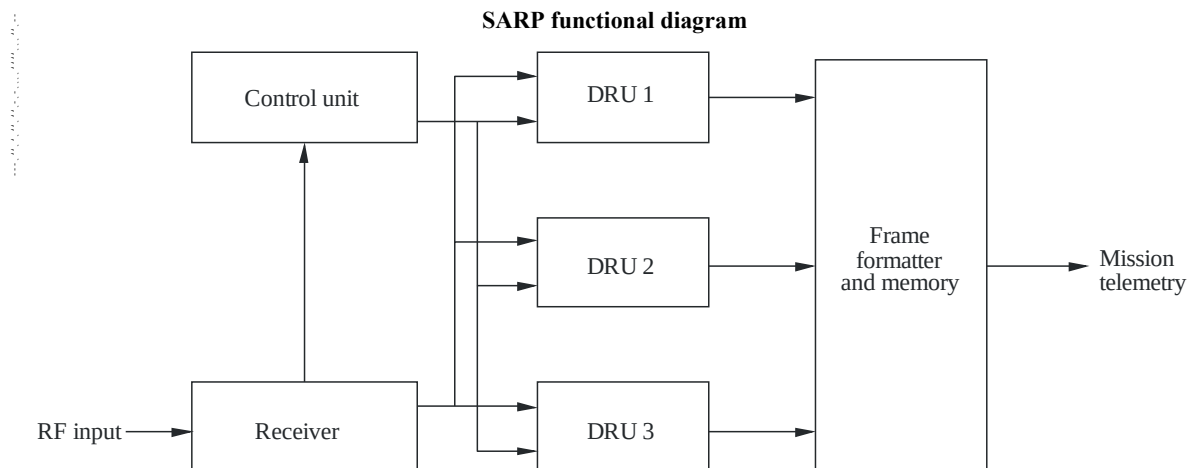
FIGURE 3
Detection of a sine wave in white Gaussian noise



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Signals above the threshold level are assigned to an on-board data recovery unit (DRU) for further processing and transmission to the Earth on the mission telemetry channel (see Fig. 4).

FIGURE 4
SARP functional diagram



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In order to satisfy SAR performance requirements in respect of low power distress beacons, the Sarsat SARP instrument has been designed to detect and process extremely weak signals. Its performance is such that any signal, C_{min} , which exceeds the local noise density level by 21 dB(Hz) ($C_{min}/N_0 > 21$ dB(Hz)) would be assigned to a DRU for additional processing. Consequently, narrow-band interfering signals meeting these criteria would cause a DRU to be assigned to it. The consequence would be that the performance of the SARP, in terms of capacity (e.g. the number of simultaneous distress messages that are able to be processed), would be seriously degraded.

The Sarsat typical figures are: noise factor = 2.5 dB (C-S SARP typical figure), nominal background noise temperature = 1000 K (C-S input parameter), attenuation between the antenna and the SARP receiver = 1.6 dB. Thus, the system noise temperature at the input of the SARP receiver (point B on Fig. 1) equals 1010 K and therefore, the noise spectral density equals $N_0 = -198.6$ dB(W/Hz).

As $C_{min}/N_0 = 21$ dB(Hz), $C_{min} = -177.6$ dBW. Therefore any narrow-band spurious emission greater than -177.6 dBW at the input of the SARP (point B of Fig. 1), would result in a degradation to system capacity.

It is then necessary to compute this maximum admissible level of spectral line at the input of the Sarsat antenna.

The Sarsat SARP receive antenna gain pattern specification is expressed according to the nadir angle in Table 2.

TABLE 2
SARP receive antenna (UDA) gain pattern

Nadir satellite angle	62	59	54	47	39	31	22	13	5	0
Gain in RHCP	3.85	3.54	2.62	1.24	-0.17	-1.33	-2.24	-3.08	-3.80	-3.96
Gain in LHCP	-5.69	-6.23	-7.52	-9.39	-11.39	-13.12	-14.52	-15.77	-17.17	-18.00
Axial ratio	6.02	5.85	5.59	5.26	4.90	4.57	4.31	4.11	3.78	3.49

Therefore, the maximum admissible power at point A of Fig. 1 equals $-177.6 + 1.6$ (losses) = -176 dBW, taking into account the highest satellite nadir angle. As the pfd is required, it is necessary to transform this figure in dB(W/m²). The equivalent surface area of an antenna having a gain G is $S = G \frac{\lambda^2}{4\pi} = 0.105$ m² corresponding to the highest satellite nadir angle. Therefore, the corresponding pfd equals $-176 - 10 \log_{10} S = -166.2$ dB(W/m²).

The required protection level is: no narrow-band spurious emission above -166.2 dB(W/m²) at the input of any Sarsat SARP satellite antenna.

4 Conclusion

Following the above computations, the conclusions and recommendations regarding the impact of spurious narrow-band emissions, on the Sarsat SARP shall not exceed -166.2 dB(W/m²) at the input of any Sarsat SARP antenna.